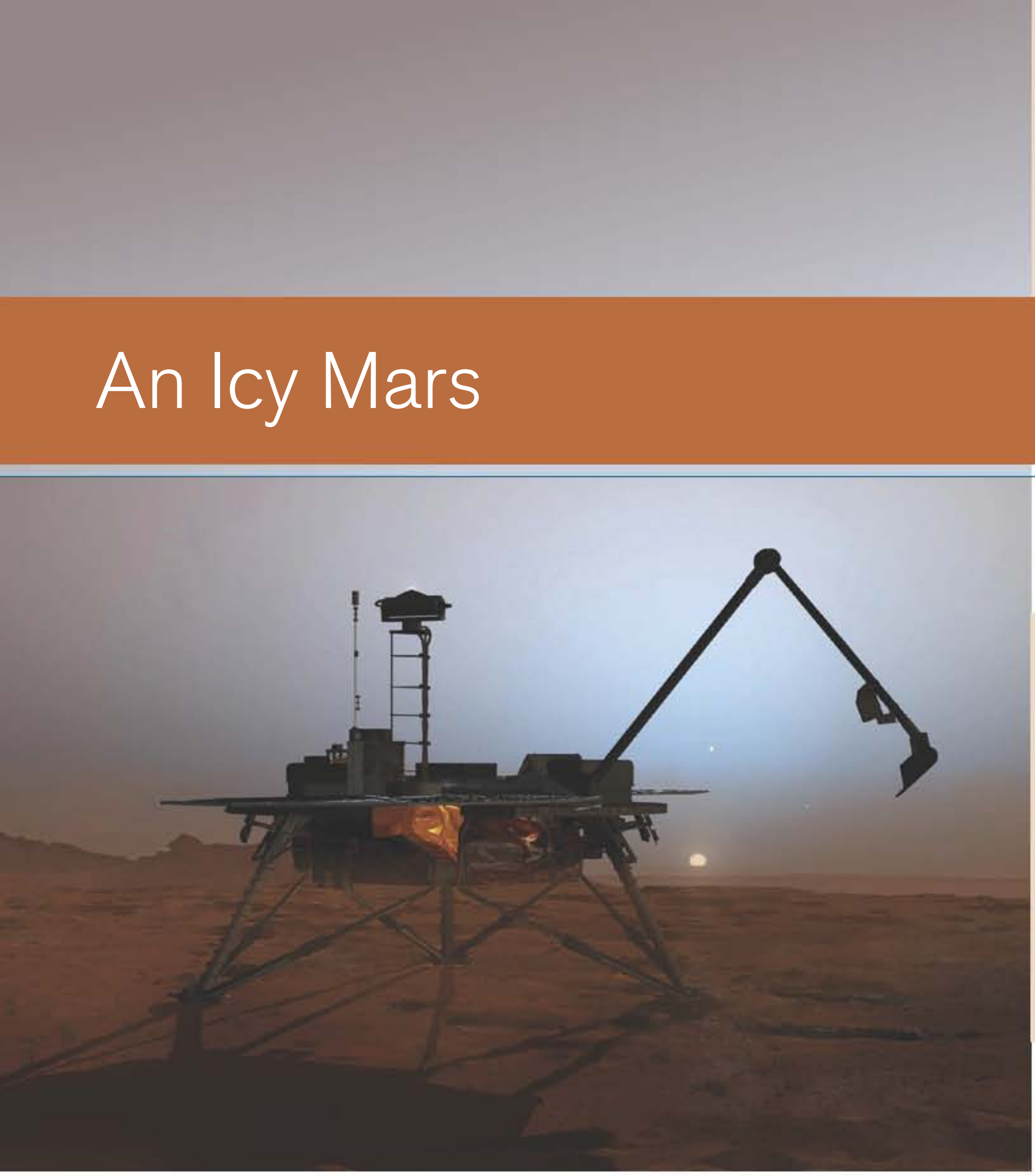


An artist's rendition of the Phoenix lander shutting down operations as winter sets in.

An Icy Mars

With the Phoenix lander, scientists have visited a Martian polar region for the first time. Tasked with finding signs of water—and in particular, ice—and conditions suitable for life, Phoenix has returned a bounty of new knowledge.

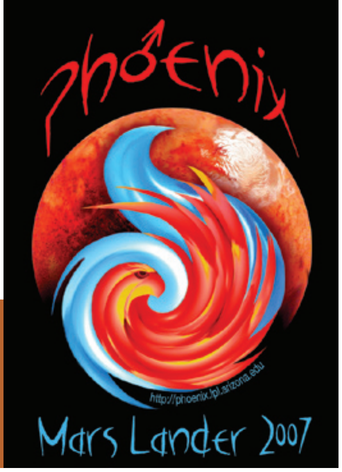
Mars is not a hospitable place for humans. Farther away from the sun than Earth by more than 50 percent, its midsummer equatorial surface temperature barely reaches the freezing point of water. The Red Planet weighs one tenth as much as Earth and has an atmosphere that's one thousand times thinner. Yet, of all the planets in the solar system, Mars (along with Venus) is the most similar to our own. But it's Mars that has generated the most speculation about alien life—fictional and real, from television characters Marvin the Martian and Uncle Martin to what were thought to be microbes brought over on Martian meteorites—a discovery announced with great fanfare in 1996 on which the jury is still out. Mars's and Earth's axes have similar tilts, at 25.2 and 23.5 degrees, respectively, leading to comparable seasonal cycles. Both have had past changes in global climate, and both have polar ice caps.

Maybe the most exciting similarity is the presence of water, believed to be essential for life—at least, what we know of as life. Although abundant liquid water can't exist, since the thin atmosphere and frigid temperatures mean oceans, lakes, or rivers would either evaporate or freeze, Mars Global Surveyor, Odyssey, and the Exploration Rovers have sent back evidence showing that Mars has substantial water frozen at its poles. Plus, there may be conditions where tiny amounts of water are unfrozen—a few loose molecules might be able to wiggle around, creating an environment in which microbes may survive. Could the poles, then, be abodes for Martian life?

Enter NASA's Phoenix mission, led by the University of Arizona and JPL. With its successful landing in May on the arctic plain at latitude 68 degrees north—roughly equivalent to the Arctic Circle on Earth—Phoenix became the first probe to visit one of the Martian poles. Phoenix's goal was to look for

Right and center: Gullies in the walls of two meteor craters in Sirenum Terra's Newton Basin.
Far right: This approximate true-color rendering, taken by the Opportunity Rover, shows hematite pebbles—nicknamed "blueberries"—strewn across an area called Berry Bowl. Researchers say the blueberries probably formed when groundwater seeped through rock and reacted, depositing the hematite spheres.

By Marcus Y. Woo



signs of water: frozen and unfrozen, present and past. Scientists also wanted to search for places where life may exist, so-called habitability zones. In five months of digging and scraping, the craft returned a bounty of data, finding surprises in the soil, seeing wispy clouds and falling snow, and for the first time, touching cold, hard, Martian ice.

WATER, WATER EVERYWHERE?

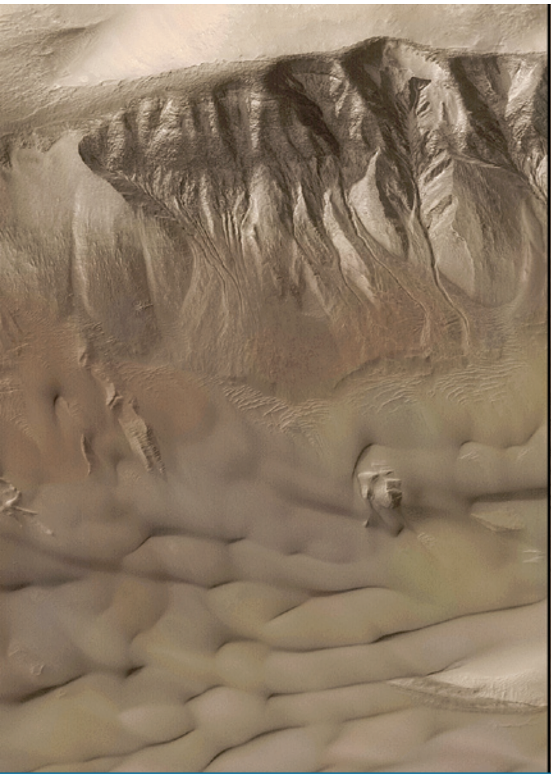
People have looked for water on Mars since at least the late 19th century, when Percival Lowell wrote about the canals he thought he saw crisscrossing the planet's surface. Since then, complex Martian waterways have been debunked, but the search for signs of water continues. In the 1970s, JPL's Viking orbiters photographed channels that appeared to have been carved by flowing water. Twenty years later, the Mars Global Surveyor found salt deposits at two craters called Terra Sirenum and Centauri Montes, suggesting they were sites where water once flowed. Over the last decade, a whole fleet of spacecraft has detected numerous signs of past—and perhaps present—liquid water, including gullies that had sprung into existence where no gullies had been before.

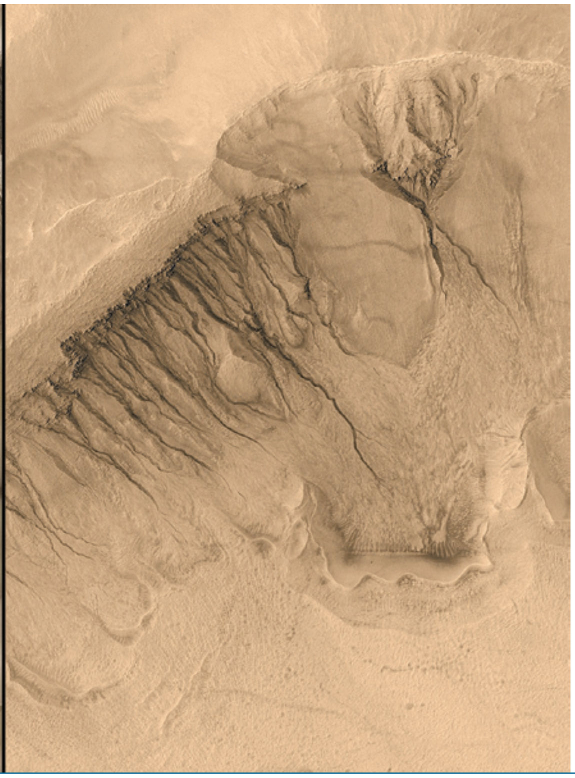
But the strongest evidence so far is in mineral deposits. The Mars Rover Opportunity found spherical pebbles of hematite, a type of iron oxide. Dubbed "blueberries" because of their size and shape, these objects may have cousins on Earth. Geologists from the University of Utah had analyzed similar hematite pebbles in southern Utah, and determined that they form when groundwater seeps through permeable rock and reacts, leaving behind minerals. After comparing the Utah pebbles to the Martian "blueberries," the researchers concluded both were formed in the same way.

But if Mars was once awash in liquid water, where did it all go? Though scientists are still unsure, one leading theory points to the once-molten nickel-iron core as the culprit. A molten core, like Earth's, is a churning furnace—a dynamo that generates an electric current. The current creates a magnetic field, a bubble that protects the planet's atmosphere from the solar wind.

Mars's core became inert roughly four billion years ago, allowing particles from the solar wind to strip away its atmosphere. As a result, any surface water evaporated and much of the water vapor was lost into space. The atmosphere also trapped heat, so that, as the air thinned out, Mars cooled dramatically.

With any liquid water that may have existed now gone, opportunities to surf on Mars may be slim. But sports enthusiasts need not despair—in 2002, the Mars Odyssey orbiter detected the signature of hydrogen,





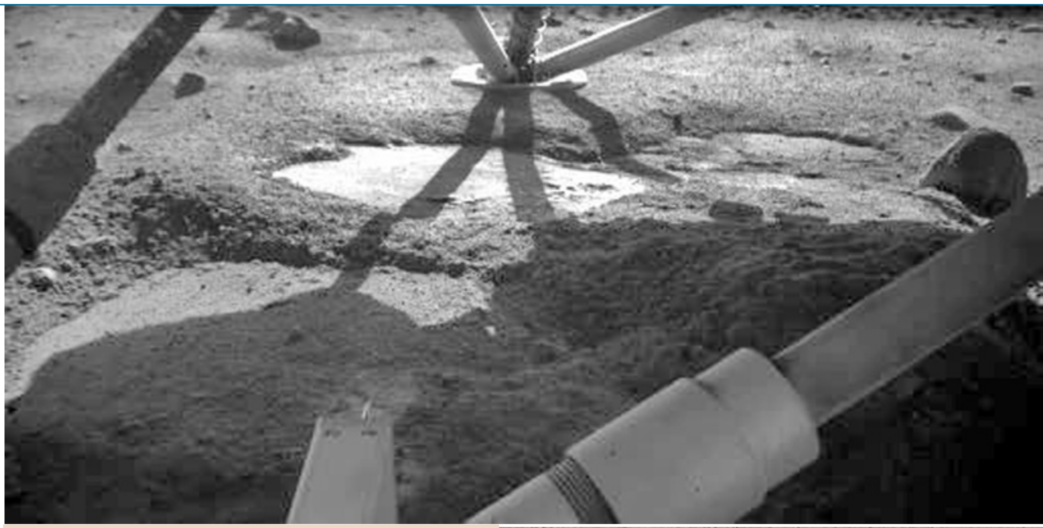
Given that more than half of all previous attempts to land on Mars had failed, the mission was anything but a slam dunk. The landing was “eight minutes of terror.”

a proxy for water, in the top meter or so of soil near the south pole. Mars may abound in frozen water—ice skating, anyone?

Scientists also want to study the poles because of what they reveal about Mars’s climate history. The tilt in Mars’s axis has shifted over the eons, meaning that in the past the northern hemisphere pointed more directly toward the sun, resulting in warmer summers.

NASA had already sent the Mars Polar Lander to the southern polar region in 1998, but it crashed upon arrival. Over the past decade, NASA’s slogan for exploring Mars has been to “follow the water,” making the search for evidence of that life-affirming molecule central to each mission. Now that it appeared water ice might be sitting tantalizingly below the surface, NASA sought redemption in another polar lander. This time, however, the plan was to visit the north pole. In 2007, when Phoenix was to be launched, the north pole was the easiest to get to. The north pole also has water ice, which is exposed during the summer, unlike in the south. In fact, the north polar ice cap is Mars’s primary source of water.

Named after the mythical bird that rose from its own ashes, Phoenix was a spacecraft reborn. Researchers built the probe by combining three instruments from the first Polar Lander (two landers had been built) and the body and two instruments from the Mars Surveyor 2001 Lander, a follow-on craft that had been built by Lockheed Martin Space Systems in 2000 but then shelved after the loss of the first lander. On August 4, 2007, a Delta II rocket launched Phoenix on its 10-month journey to the Red Planet.



Above: This picture taken of the area below the lander shows a smooth, flat patch that looks like ice, prompting the scientists to exclaim, “Holy cow!”
Right: Called Dodo-Goldilocks, this trench revealed white stuff that has been confirmed to be water ice.

Given that more than half of all previous attempts to land on Mars had failed, the mission was anything but a slam dunk. The landing was “eight minutes of terror,” says Leslie Tamppari of JPL, the mission’s project scientist and a Phoenix coinvestigator. (Peter Smith, of the Lunar and Planetary Laboratory at the University of Arizona is the principal investigator.) Because of its bigger payload, Phoenix couldn't use airbags to cushion its fall like the highly successful Mars rovers had. It had to use thrusters to slow its descent—as the first Mars Polar Lander had—adding another element of uncertainty. After all, the Polar Lander is believed to have been lost when its thrusters cut off too soon. It took dozens of people working full time for four years to plan the landing, according to Tamppari. When the craft touched down safely on May 25, 2008, "there was a huge eruption of celebration," Tamppari recalls. "It was a fabulous day."

HOLY COW!

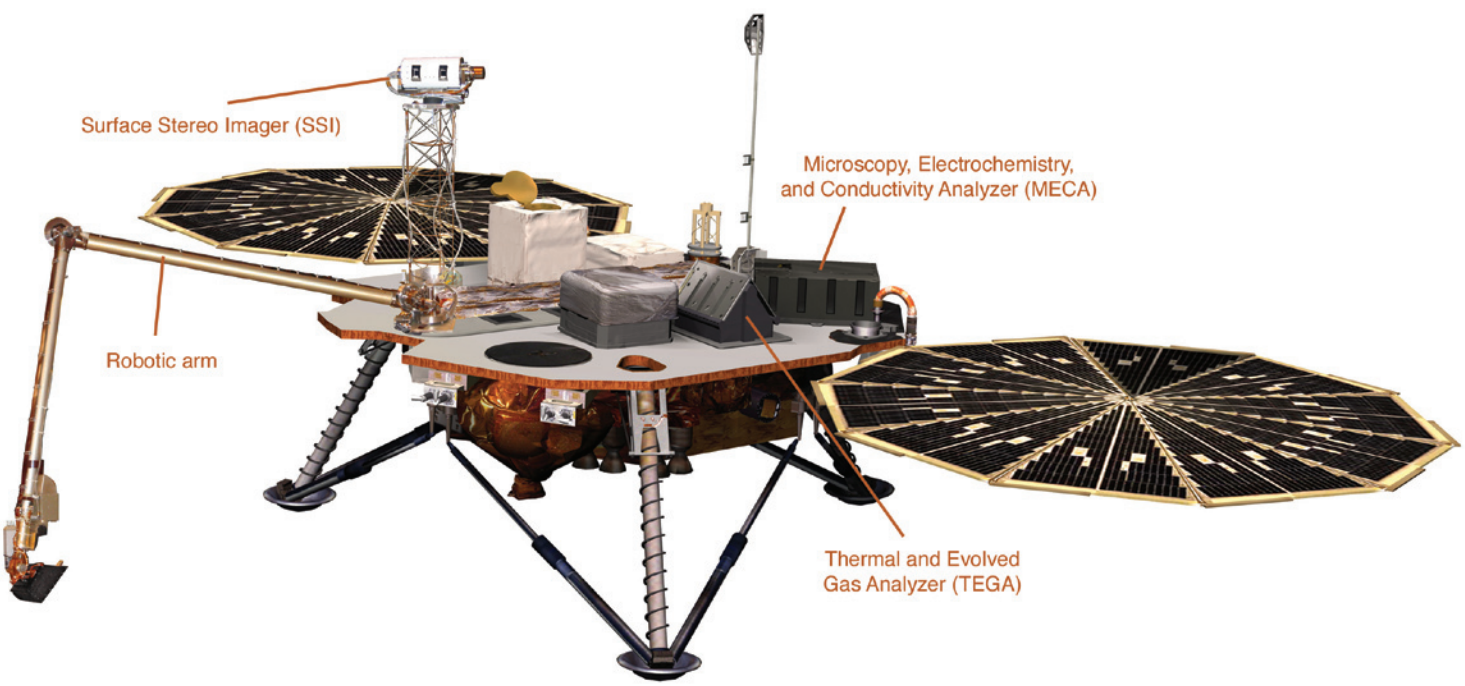
Within a few hours, Phoenix had sent back its first photos. The terrain was covered with polygon-shaped features indicative of subsurface ice. The shapes are formed when ice temperatures change, cracking the surface. Dirt falls into these cracks and keeps them open. "It was really an incredible moment to be one of the first people on Earth to view these pictures of Mars," Tamppari says about the flat Martian surface dotted with rocks. "From a geologist's perspective, this is beautiful terrain."

Scientists converged on mission headquarters in Tucson, Arizona—even though Phoenix, some 185 kilometers up Interstate 10, might've been more appropriate, Tamppari points out. More than 80 scientists, engineers, and students would spend the next three months in Tucson living and working on Mars time. The Martian day, called a sol, is about 40 minutes longer than an Earth day, meaning that the team's day-night cycle slowly diverged from that of the world around them. After about five weeks, they were a day out of synch.

On just the sixth sol, Phoenix took what Tamppari calls the mission's "holy-cow image"—a picture of the area just below the lander, where the thrusters had blown away the top layer of soil, exposing a smooth, white surface. It appeared as if Phoenix had already found the top item on its list, ice. But scientists couldn't confirm this discovery until they got a closer look.

Phoenix's 2.35-meter robot arm dug several shallow trenches around the site, each only a few centimeters deep. The first trench, called Dodo-Goldilocks (the team named all the sites after fairy tales), revealed white patches, bright against the dark red of the Martian soil. Still, scientists couldn't be sure, because the white stuff could also be salt deposits, another item that Phoenix hoped to find. But when some of the white patches shrank over the next few days, scientists became convinced that they had found ice. In the thin, Martian atmosphere, ice sublimates—it goes from solid to gas, skipping the liquid stage. Salt doesn't do that. It stays put. For the first time, Martian ice was within a robotic arm's reach.

Over the next few weeks, Phoenix would scoop up some of the suspected ice and deposit it in one of its instruments, the Thermal and Evolved Gas Analyzer (TEGA). TEGA is a set of eight identical ovens, each about the size of a ball-point pen's ink cartridge, that can slowly heat a sample to



temperatures up to 1,000 degrees Celsius. Each oven can only be used once. Heating a sample releases any volatile material, and a built-in mass spectrometer identifies atoms, molecules, or molecular fragments. Tamppari and principal investigator Peter Smith compare it to baking cookies at home. By smelling the scents wafting through the house, hungry guests can tell the difference between chocolate-chip and oatmeal-raisin. After baking the samples, TEGA confirmed that the white stuff was indeed water ice. This procedure proved tougher than anticipated, since the clumpy soil kept getting caught on the screen covering the ovens that was supposed to keep large particles from clogging the tiny chambers.

Snow White, another trench dug two meters away, also uncovered ice. But this ice wasn't bright and white—it was dirty. Scientists had assumed that most of the ice on Mars formed when water vapor seeped into the soil and froze, creating a thin, uniform ice layer everywhere. The fact that pristine and dirty ice were found right next to each other shows a variability that Tamppari says surprised the scientists.

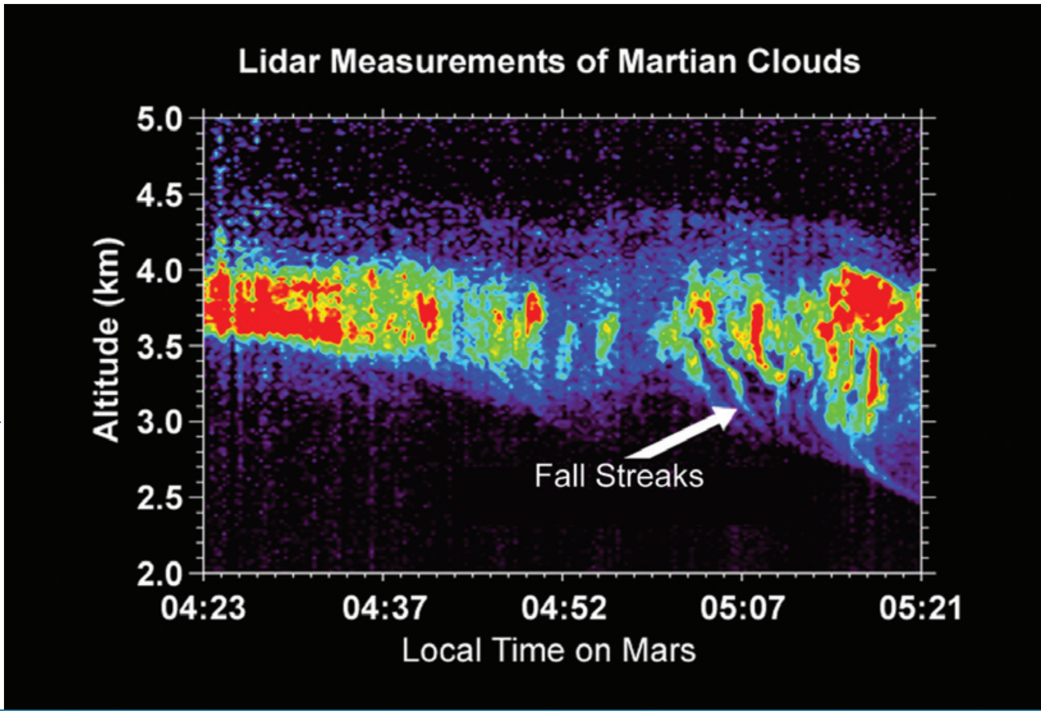
In addition to ice, TEGA found carbonates, a class of minerals formed when water, carbon dioxide, and other minerals react. Given all the carbon dioxide in Mars's atmosphere, any past water would have left the soil with abundant amounts of carbonates. Most of the carbonates proved to be calcium carbonate, with possibly other kinds as well.

The lander was also equipped with an instrument called the Microscopy, Electrochemistry, and Conductivity Analyzer (MECA), part of which is a wet chemistry lab that dissolves bits of soil for analysis, helping to determine whether the site is suitable for life. Scientists found the soil to be slightly alkaline, with a pH just above 8—comparable to tap water, and friendly for life.

Curiously, this measurement differed from what the rovers found in the equatorial region, Tamppari says. There, the soil was slightly acidic—a pH just below 7. "Something different has happened," she says. "These two areas were not created equally." The polar regions also differed in that Phoenix has so far not found any sulfates, which were present along the equator. Further analysis may still reveal sulfates, however.

In another surprise, MECA found a molecule called perchlorate in the soil. Perchlorate is often found in rocket fuel—although not Phoenix's, whose descent engine used pure hydrazine. Perchlorate is an oxidant that can break down organic molecules and is toxic to humans. But it also occurs on Earth naturally—in particular, in Chile's Atacama Desert, where some microbes use it as a source of energy, Tamppari says. So scientists still don't know whether it's good or bad for life.

Phoenix also has a lidar, analogous to a radar device that uses light instead of radio waves, that has gathered the most detailed data ever taken on the lowest five to eight kilometers of the atmosphere. Called the Martian boundary layer, this region is where surface and atmospheric temperature changes cause the air to mix. The instrument fires a laser into the sky, and the light bounces off particles of dust or ice. The time it takes for the laser to bounce back tells how high the particles are, and the amount of light reflected back tells how many particles there are. Using the lidar and Phoenix's cameras, scientists tracked the formation of clouds at night and, for the first time, saw falling snow, which sublimated before hitting



A thin layer of water frost forms on the ground around the Phoenix lander at 6 a.m. on August 14, 2008.

the ground.

Tamppari had previously studied water vapor in the Martian atmosphere, using infrared instruments aboard Mars orbiters to analyze clouds. The smallest areas the orbiter could resolve were 60 to 100 kilometers wide. As a result, she was surprised when Phoenix snapped pictures of wispy clouds drifting across the sky. “I thought the clouds would be more of a uniform haze,” she says. Instead, they spanned a wide range of densities.

CONSUMED BY ICE

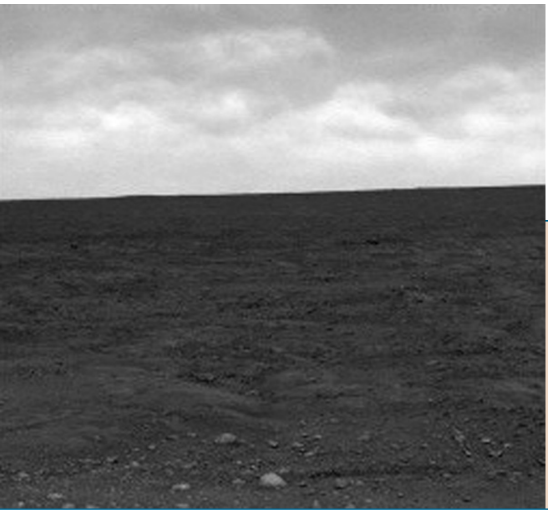
Phoenix landed during the northern hemisphere’s summer, when the daytime temperature was around a balmy zero degrees Celsius. As the weeks passed, temperatures dwindled and the air pressure dropped. Water frost started to form on the ground. Winter would bring increasing hours of darkness, and without the sun to feed its solar panels, Phoenix would slowly die. In late October, the lander was running on its last gasps of power, struggling to recharge itself. Communication with the craft became intermittent. By the beginning of November, Phoenix went silent for good.

Originally slated to last three months, Phoenix had managed to go for five. This may seem like a short lifetime, especially after we’ve been spoiled by the rovers that have turned a 90-day mission into an ongoing five-year sojourn. These rovers, however, are in the equatorial region, where sunlight will always supply power. The poles are a far harsher place, and Phoenix sits frozen, powerless, and alone in the dark. The spacecraft will be encased in a thick layer of dry ice, and the lander’s electronics are unlikely to survive such bitter cold.

When summer returns in a few months, scientists will try to nudge Phoenix awake. The lander can switch into a mode called Lazarus that allows it to recharge itself and return to life. But any number of things could happen in the meantime, Tamppari says. Accumulating snow and ice could crush the craft and break its solar panels. “Nevertheless, we’ll plan to listen for the spacecraft—just in case.”

So far, there’s no plan to revisit the poles. The next mission to Mars will be the Mars Science Laboratory, a Mini Cooper–sized rover destined for more temperate climates, whose 2009 launch date has just been postponed for two years.

The phoenix, a symbol of immortality, renews itself in fire. From its own ashes, the bird rises to live again. Consumed not by fire, but by ice, the Phoenix lander, though, has probably taken its last picture and sent its last byte of data. The most groundbreaking results—the discovery of ice, carbonates, and perchlorate; the measurements of Mars’s alkaline soil; and the accumulated weather reports—will soon be published in a series of four papers in the journal *Science*. Indeed, the spacecraft has provided enough data to keep scientists busy for years, conferring on this phoenix its own kind of immortality. e&s



Far left: The lidar provides a cross section through the clouds passing overhead. Falling snow can be seen as vertical streaks at the base of the cloud beginning at about 5 a.m., Mars time. At altitudes of around three kilometers, fast winds curve the streaks.

Left: During the early afternoon hours of September 18, 2008, the Surface Stereo Imager captured this image of clouds moving eastward across the Martian horizon.